Understanding the Asymmetry in the Energy Response of the KamLAND Detector

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KamLAND is a new reactor neutrino oscillation experiment under construction in Japan. A complete characterization of the detector response is of utmost importance in understanding the rare neutrino signals. We investigated how one can improve this understanding if a 4π calibration source deployment system is used in the calibration.

We studied the energy response asymmetry by generating isotropic light along the vertical z axis and the x axis on the equatorial plane. The response $R(x, y, z)$ in the x-scan is symmetric about the center of the detector (i.e $R(x, 0, 0) = R(-x, 0, 0)$). The z response, however, is not symmetric due to the reduction of photocathode coverage near the chimney and its opacity.

We introduced further asymmetry by inserting an opaque plate, whose unit normal vector is ($1/\sqrt{2}$,$1/\sqrt{2}$,0), at 45° from the positive x-y quadrant on the equatorial plane in our simulation. The detected light signal is reduced by 1.7% for an isotropic source at the center of the detector. One can imagine an asymmetry in the real detector response at this level because of the complex suspension system for the central vessel of the detector. We calculated the response for an isotropic source at different points on the x and z axes in the presence of this plate, and normalized this response to that in the absence of the plate at the same source location. Figure 1 shows this relative response for different x and z locations. The asymmetry in the relative response is more pronounced in the x-scan. The shape of the relative response function in the z-scan can arise from effects other than a geometric effect. For example, a combination of uncertainties in the scintillator attenuation length and the light output of the calibration sources can produce a relative response curve that resembles that in the top panel of Figure 1.

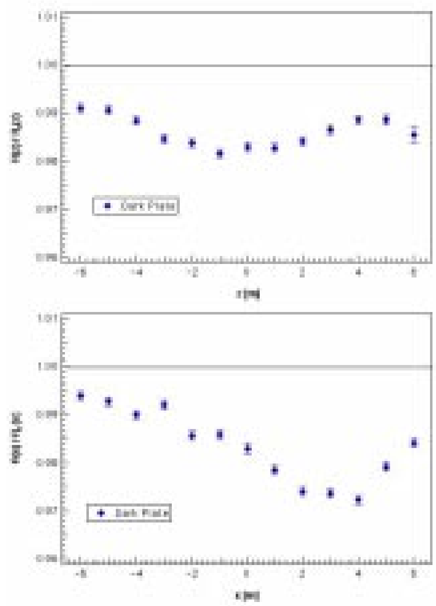

Figure 1: Relative detector response in z (top) and x (bottom) scans.

We also investigated how the uncertainty in the scintillator attenuation length would affect the energy scale. We found that a 3% uncertainty in the attenuation length would correspond to a 2% uncertainty in energy. Because the neutrino spectral shape analysis requires an energy uncertainty of better than 2% [1] and certain asymmetric effects in the detector can be misinterpreted if the off-axis deployment capability is not incorporated, a 4π calibration deployment system [2] will be installed in KamLAND.

Footnotes and References

[1] see report by Okada et al, *KamLAND Energy Resolution Requirements*.

[2] see report by Okada et al, *KamLAND Calibration and Monitoring Source Deployment*.